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6. AUTHOR(S)
Shihab Shamma and Krishnaprasad, P.S.K.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Electrical Engineering & Institute for Systems Research
University of Maryland, College Park, MD 20742

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NL
110 Duncan Ave. Suite B115
Bolling AFB, DC 20332-0001
Dr John F. Tangney

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13. ABSTRACT (Maximum 200 words)

Over the last year, work has progressed in the three basic areas that are emphasized in this proposal: I. Peripheral auditory implementations; II. Auditory cortical processing; III. Theoretical analysis of neural network architectures. In the first topic, we have completed a detailed analysis and implementation of the early auditory model originally formulated in the previous grant period. Specifically, we have determined the underlying mechanisms that give rise to noise robustness and self-normalization in the early auditory spectra. A patented VLSI implementation of the model has been accomplished. In the second area of research, we have completed a survey of response properties in the anterior auditory field, especially with regard to the cells' responses to FM and single tone stimuli. Finally, in the third focus area, we have developed new recursive algorithms (mimicing recursive neural network architectures) for building systematically, approximate basis function representations. The new algorithms known as orthogonal matching pursuit algorithms are applicable to a wide class of problems, ranging from fitting radial basis function approximations to wavelet-bases models for transfer functions of linear systems.

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Department of Electrical Engineering
Systems Research Center
Institute for Advanced Computer Studies
University of Maryland
College Park, MD 20742

Shihab A. Shamma, Ph.D.
Associate Professor
Bitnet sas%src.umd.edu@umd2
Arpanet sas@src.umd.edu
Telephone 301-405-6842

March 30, 1994

Dr. John Tangney
AFOSR/NL, Building 410
Bolling AFB, DC 20332-6448
Re: F49620-92-J-0500

Dear John:

This letter is in reference to the information that you requested regarding the progress report due last September. As you know, we have made significant progress in modelling and gathering physiological and psychophysical data on the functional organization of the primary and anterior auditory cortex. These results are detailed in the seven reports that I sent to you last week. In addtion, we have obtained a patent on a VLSI implementation of the cochlea, and a publication describing this circuit is to be out in IEEE circuits and Systems next month. My co-investigator, Krishnaprasad has appended below a description of the progress made on his part under this grant, and a listing of the publications that have resulted from it. Please let me know if you wish me to send you any copies of these reports. Thanks much for your support.

Research on Neural Networks (P.S.Krishnaprasad and Graduate Students)

In earlier work on this project, techniques based on wavelet transforms were used to (a) provide rigorous arguments for approximation properties of feed-forward neural networks; (b) devise algorithms for approximation and identification of distributed parameter linear systems. In recent work, new recursive algorithms have been devised for building systematically, approximate basis function representations. The new algorithms known as orthogonal matching pursuit algorithms are applicable to a wide class of problems, ranging from fitting radial basis function approximations to wavelet-based models for transfer functions of linear systems. These new algorithms are well-equipped to work with raw data as well as data subject to preliminary processing. It is of further interest that these algorithms are well-suited to the exploitation of certain forms of a priori knowledge (in the time-frequency plane). Several papers have resulted from this work, a software package is now available for use on Sun workstations, with a graphical user interface. One M.S. student has put the techniques and software to good use in the identification of the dynamics of flexible beams with surface mounted piezo-electric sensors and actuators (so-called smart structures). The algorithms are fast enough to merit coreal-time applications.

In continuation of the above effort, we have started to study carefully the problem of vector field approximations in nonlinear dynamics via basis vector fields. Prior efforts ignore the fundamental geometric differences between vector field approximations and function approximations. We note for instance the use of radial basis functions in adaptive control. Our effort, based on an understanding of geometric approximation techniques for vector fields by polynomial vector fields, is likely to yield new insights into the structure of recurrent networks and more generally locally interacting dynamical systems. A graduate research assistant supported by AFOSR (Herbert Strumper) is involved in this study, as a part of his Ph.D. research.

The recent discoveries in thalamo-cortical oscillations have led to the suggestion that oscillatory neural networks are playing an important part in the solution to the so-called "dynamic binding problem", where coherent oscillations encode the binding together of features of an image in a receptor field. Somewhat influenced by these exciting developments, we undertook a deep study of the properties of networks of oscillatory neurons (sometimes called rotor neurons). We have a better understanding of the mean-field theory of a class of such networks. We have proved new convergence theorems using arguments based on LaSalle's invariance principle. We have further insights into asymptotic behaviors. New implementations in analog networks are being considered. One M.S. student (Eric Justh) is involved in this project. He is however an NSF Graduate Fellow and hence does not need support from AFOSR. His thesis is under preparation. In addition to the papers listed below, several papers are under preparation including one for presentation at an April Symposium sponsored by the National Academy of Sciences Board on Mathematical Sciences. These and other papers also influenced by the current AFOSR project will be provided for review.

Papers and Reports

R. Rezaiifar, Y.C. Pati, P.S. Krishnaprasad and W. P. Dayawansa, "Wavelet Based Identification of Smart Structures with Surface Mounted Actuators and Sensors", (1993), in *Proceedings of 32nd IEEE Conference on Decision and Control*, IEEE, New York, pp 486-491.

Y.C. Pati, R. Rezaiifar and P.S. Krishnaprasad, "Orthogonal Matching Pursuit: Recursive Function Approximation with Applications to Wavelet Decomposition", (1993), in *Proc. 27th Asilomar Conference on Signals, Systems and Computers*, Nov. 1-3, 1993.

Y.C. Pati, R. Rezaiifar, P.S. Krishnaprasad and W.P. Dayawansa, "A Fast Recursive Algorithm for System Identification and Model Reduction using Rational Wavelets", (1993), in *Proc. 27th Asilomar Conference on Signals, Systems and Computers*, Nov. 1-3, 1993.

Sincerely,

Shihab A. Shamma